Preliminary Las Campanas Intake Sediment Study

prepared for CH2M-Hill, Albuquerque
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September 20, 2001

Note: This document is based on a preliminary, pre-design evaluation and is subject to revision as design progresses. Several of the alternatives identified for sediment disposal from the proposed sedimentation basin are speculative and are presented herein for purposes of discussion only.

Study Objectives:

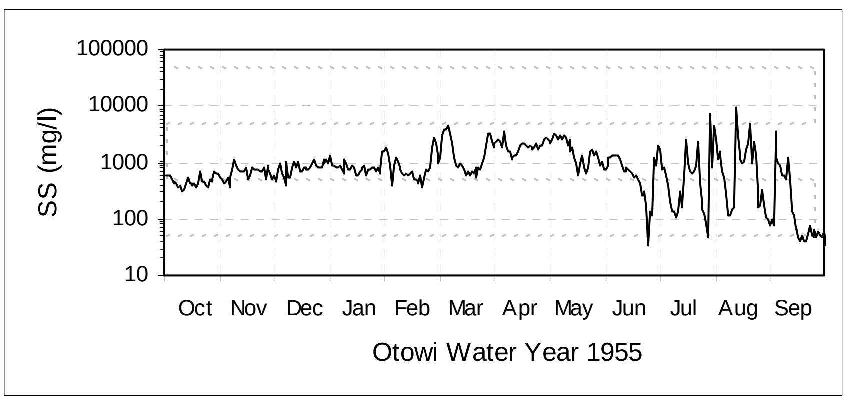
(1) To draw together and summarize the Rio Grande suspended sediment (SS) data pertinent to design of a water intake for Las Campanas at on the east bank of the Rio Grande at Buckman, NM. Particular concern is directed toward the months May-September, the season in which intake performance is more likely to be of critical concern.

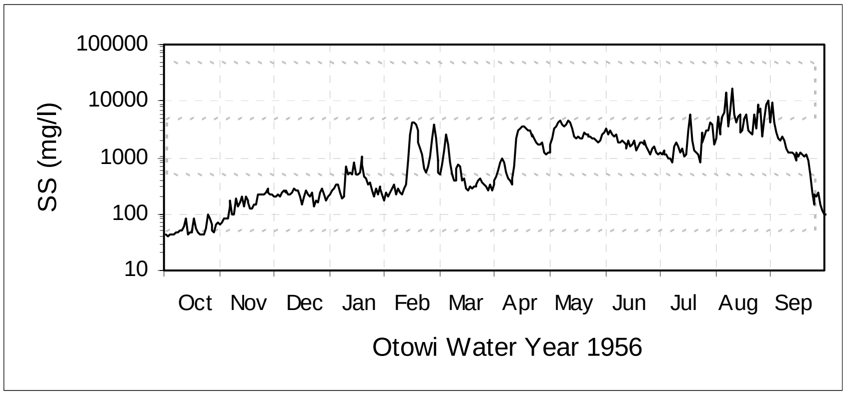
(2) To assess sediment issues related to the operation of the intake and the proposed sediment pond located some thousand feet east of the river bank on a terrace overlooking the Canada Ancha. The findings presented here should be reviewed in conjunction with final design.

Part One: Data Summary

Rio Grande SS load at Buckman is described by historic USGS stream gage and water quality data available at the Otowi gaging site, four miles upstream of Buckman. No diversions and only minor ephemeral tributary confluences lie between Otowi and Buckman.

Daily SS concentration at Otowi has been recorded since 1955. The 45-year record illustrates the river's erratic nature. The plotted record follows. (A "water year" begins in October before the corresponding calendar year.) General observations are drawn after the plots.

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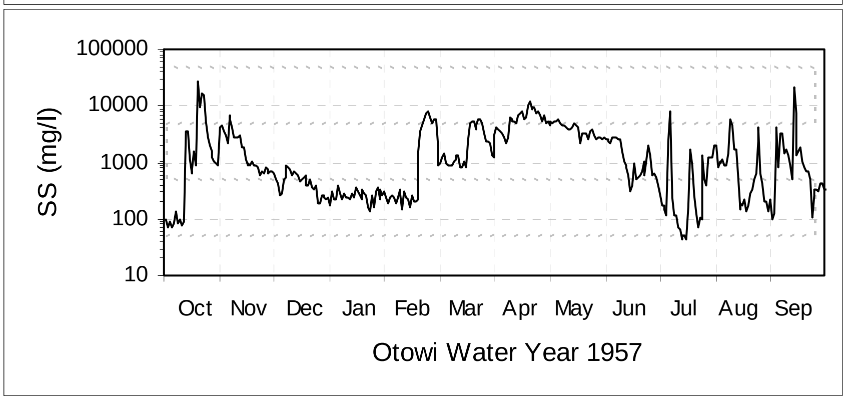
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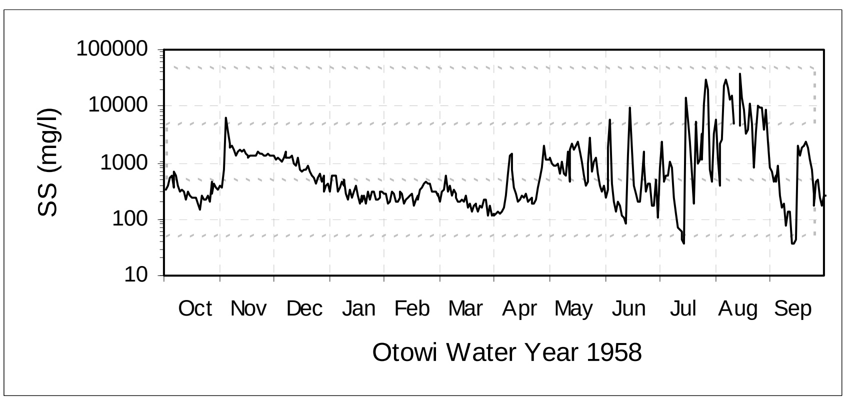
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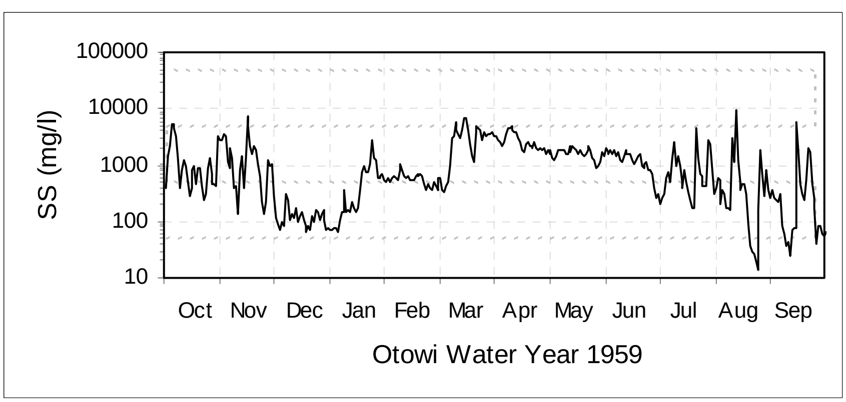
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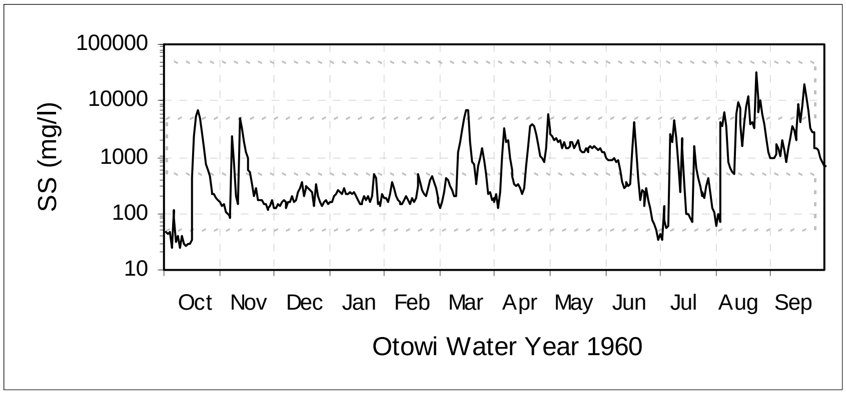
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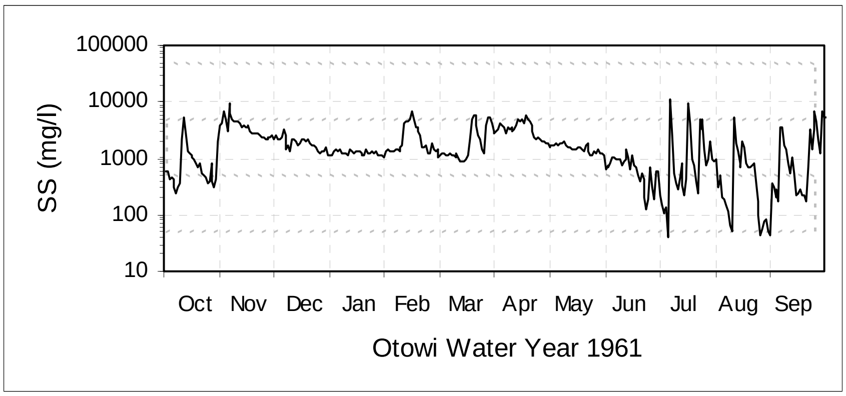
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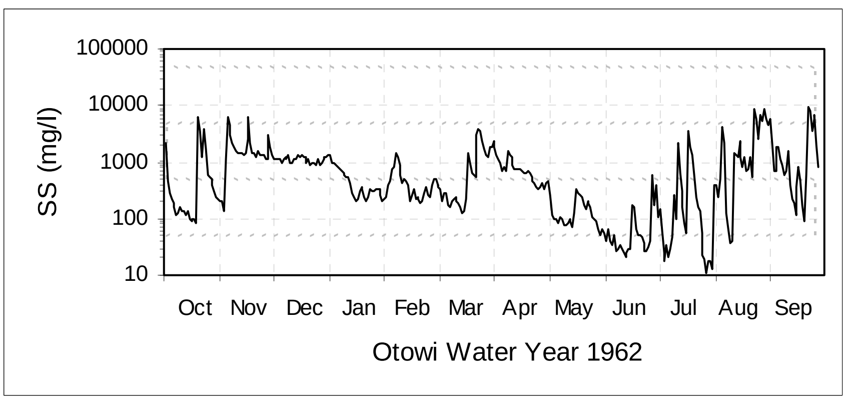
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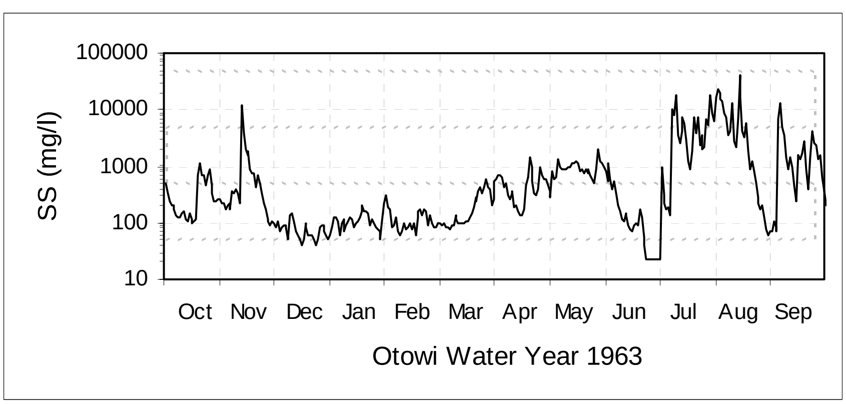
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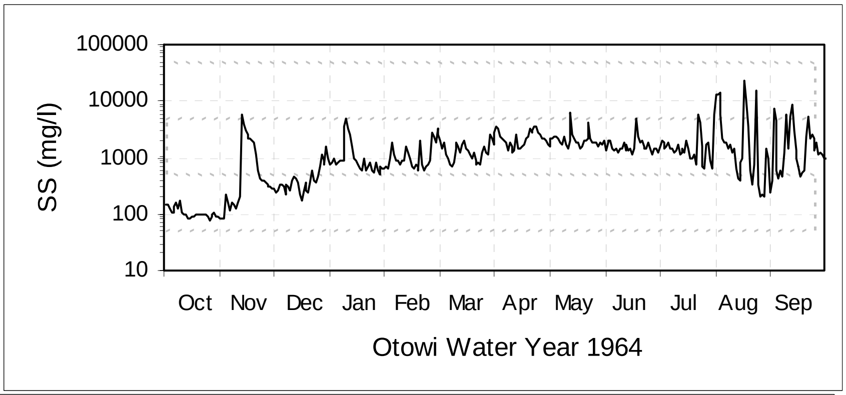
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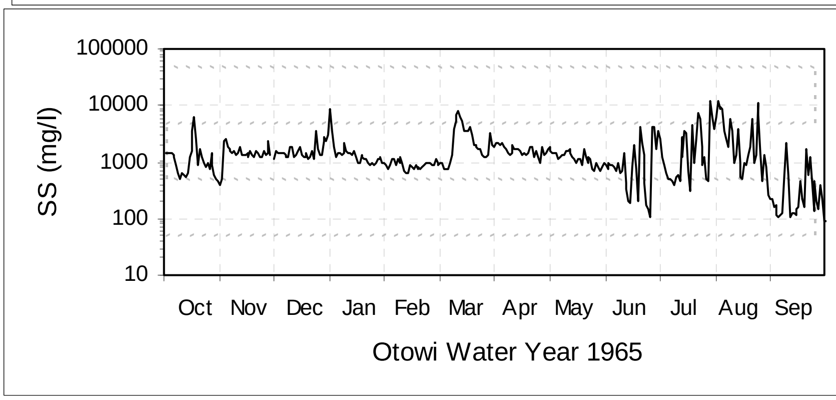
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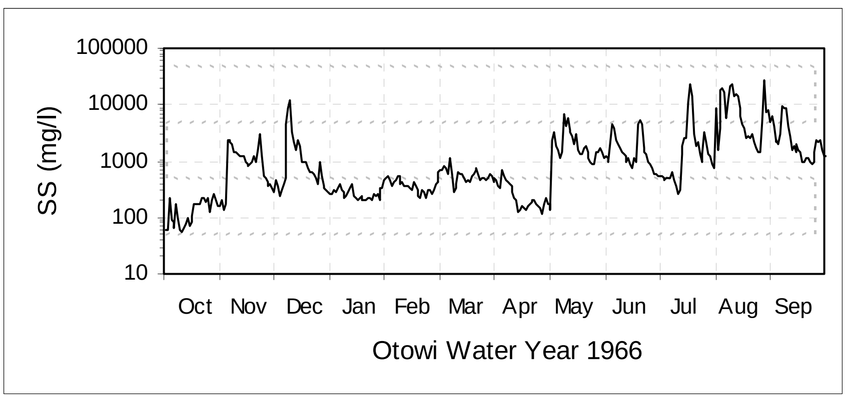
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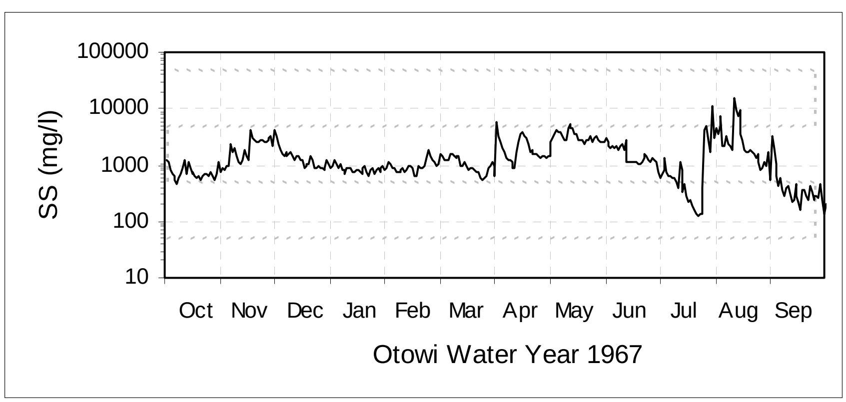
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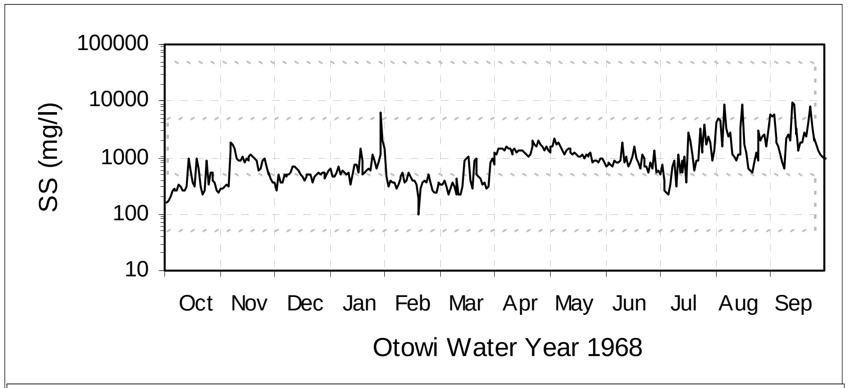
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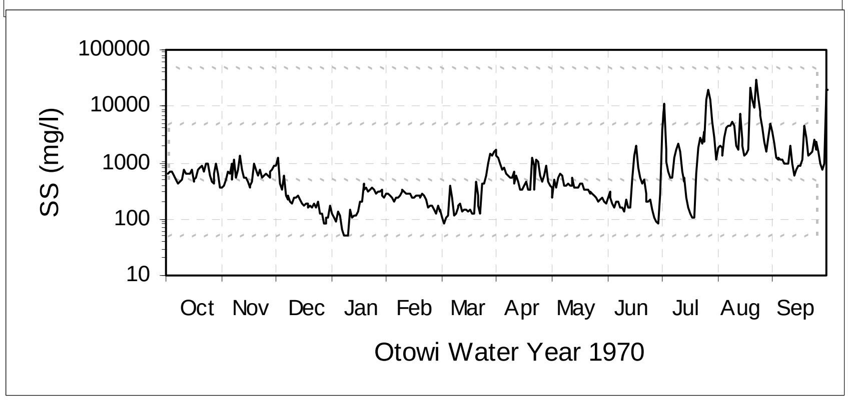
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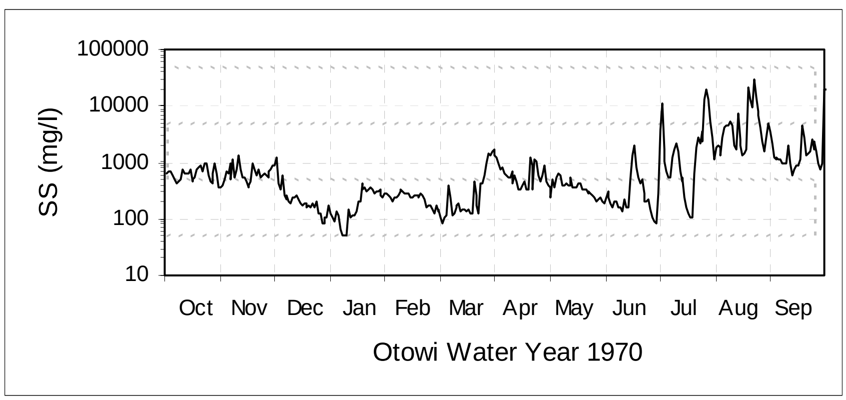
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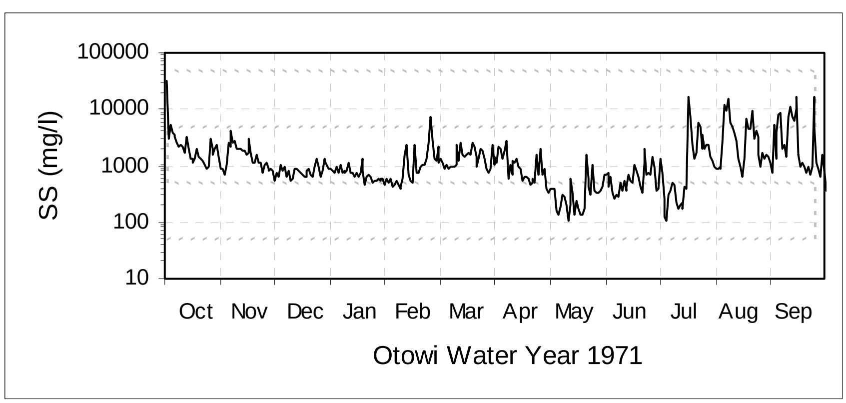
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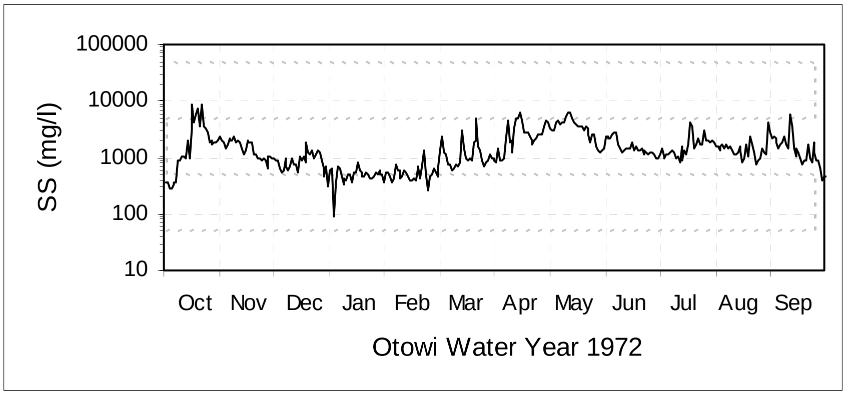
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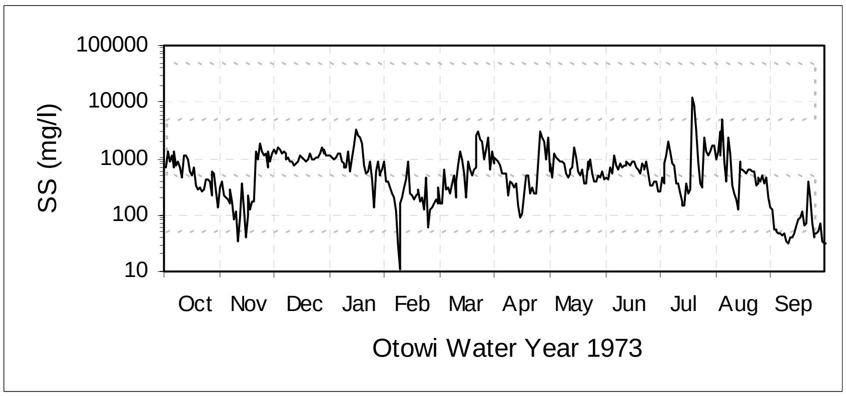
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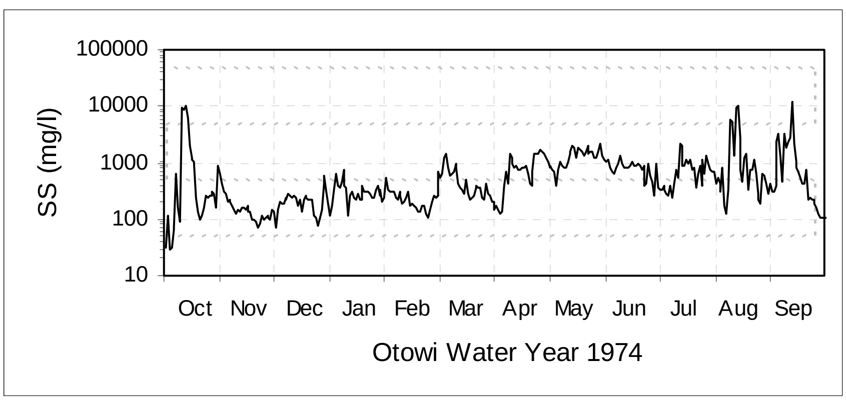
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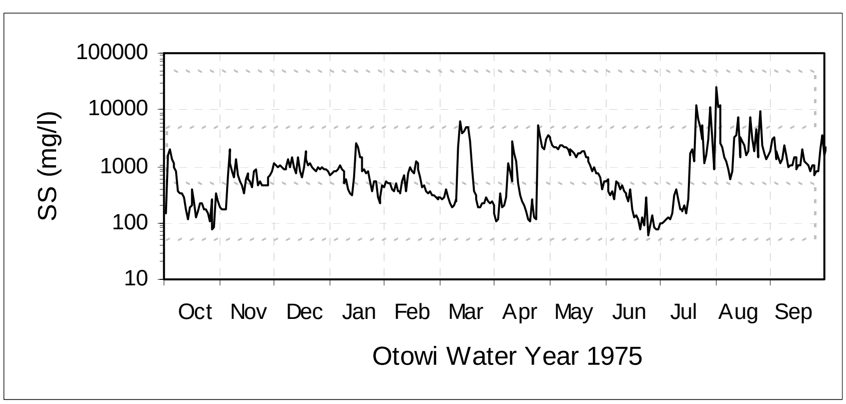
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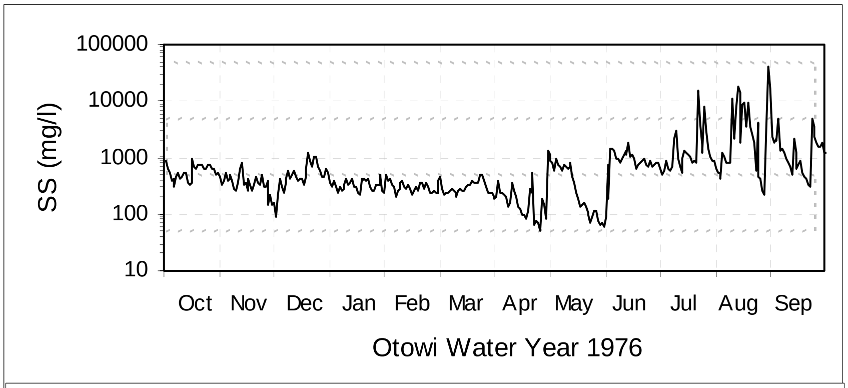

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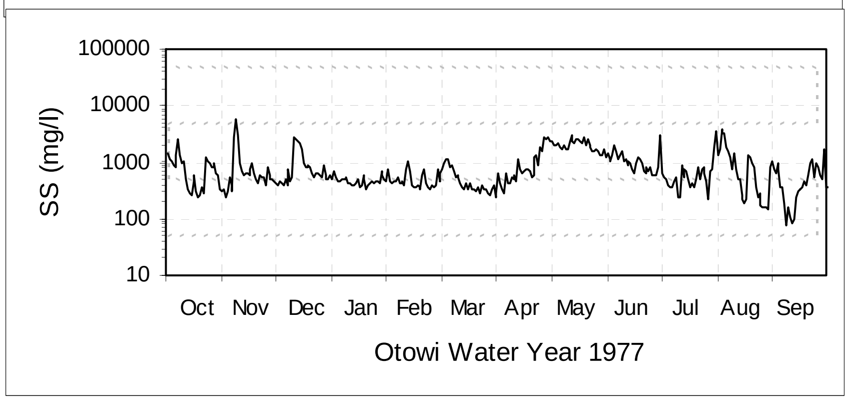

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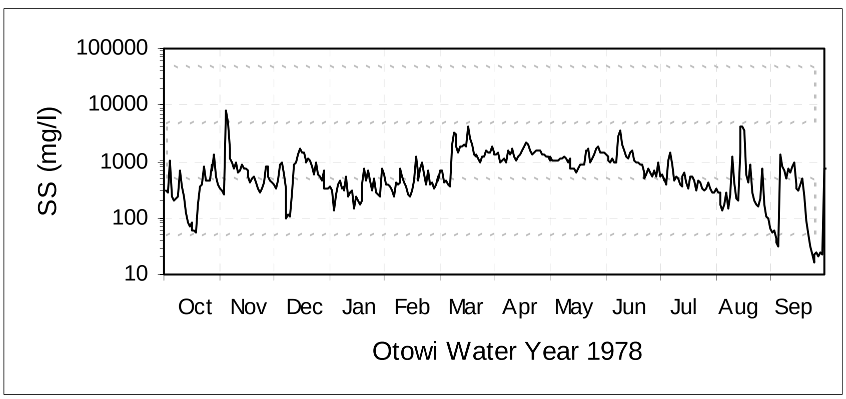

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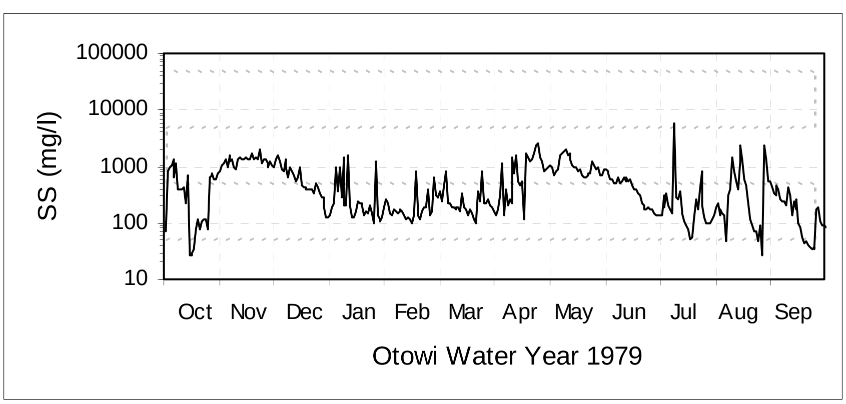

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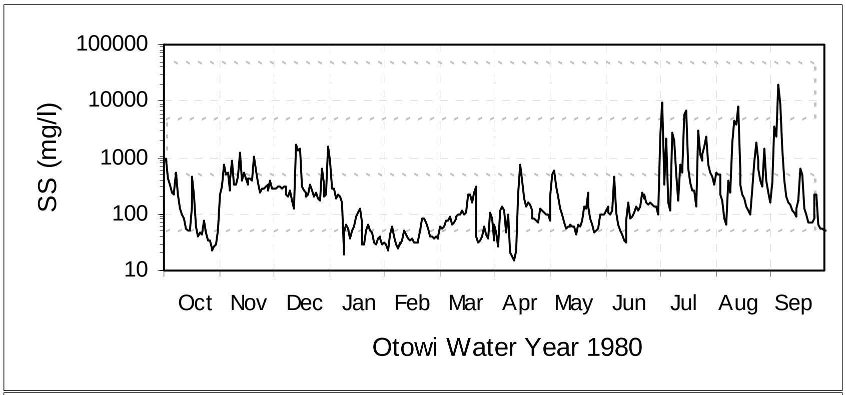
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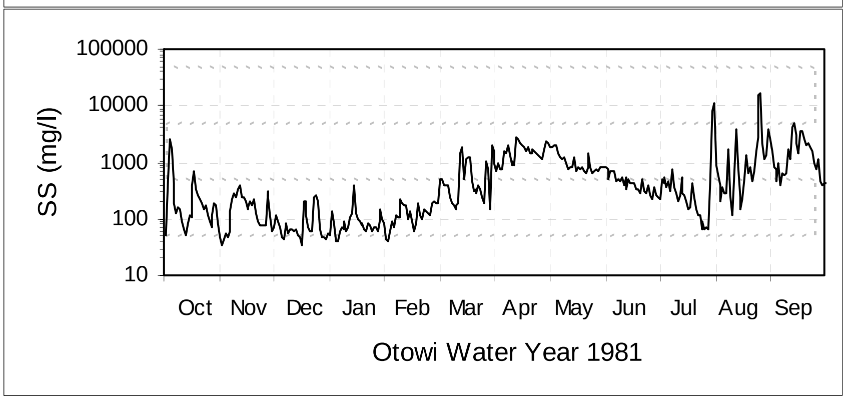
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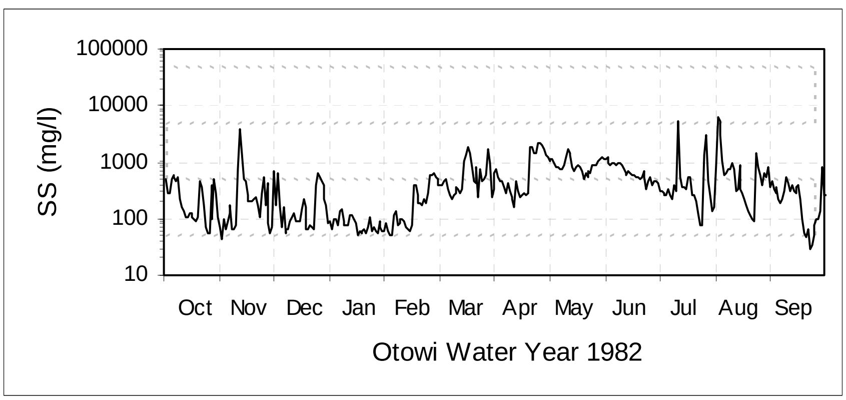
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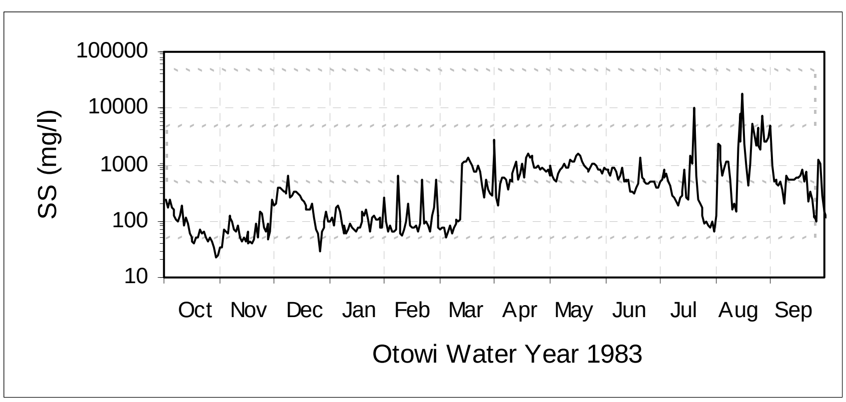
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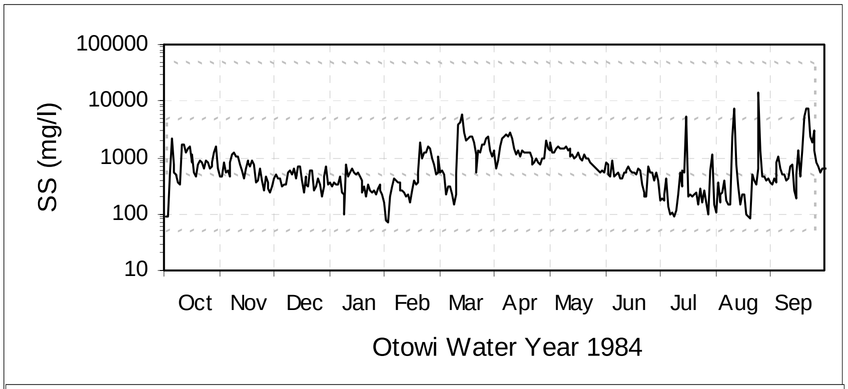
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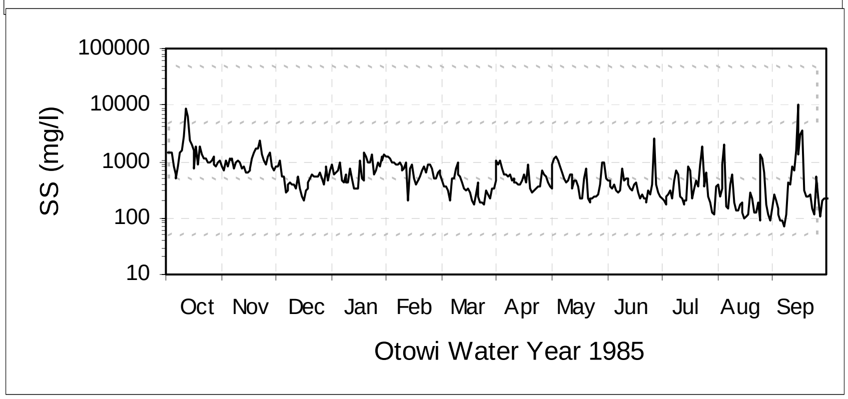
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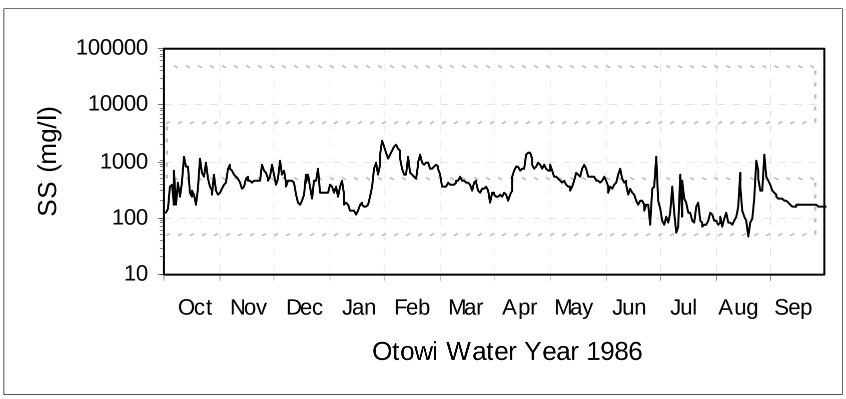
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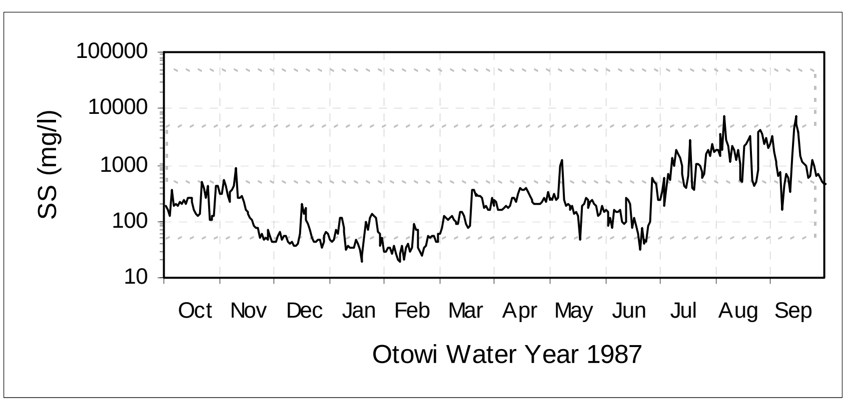
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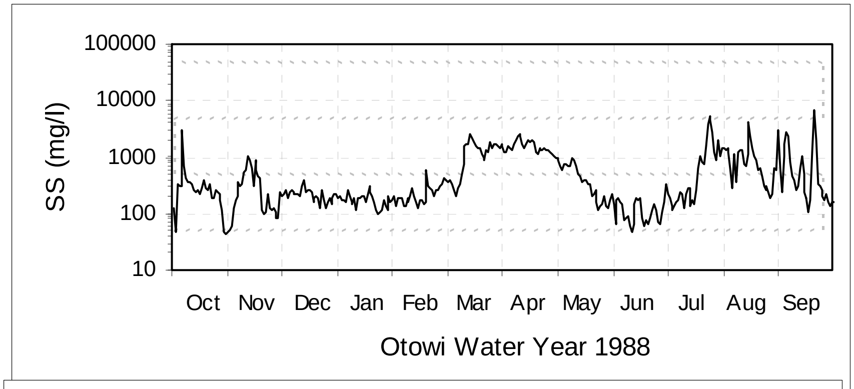
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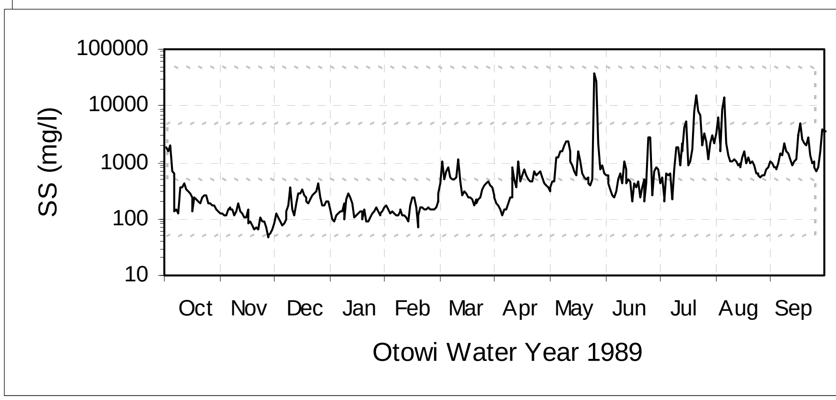
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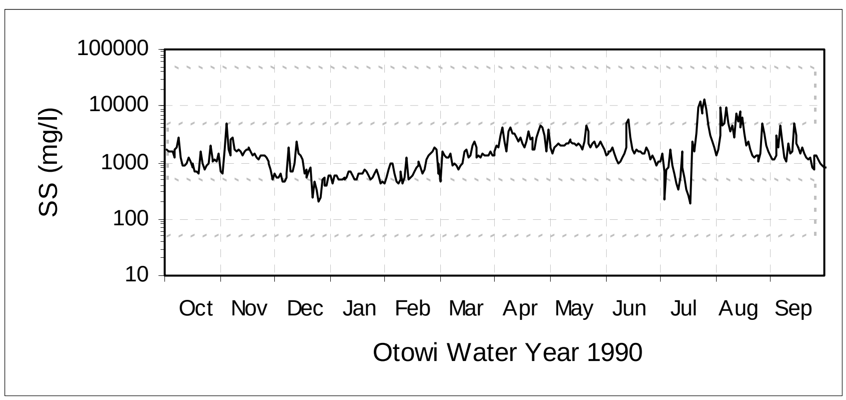
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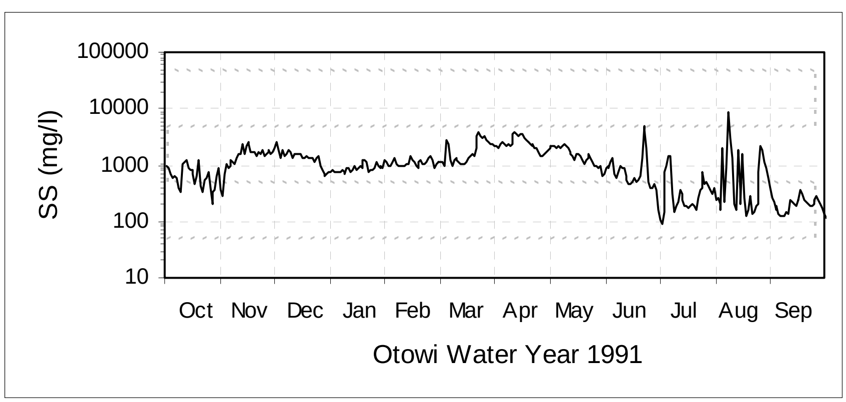
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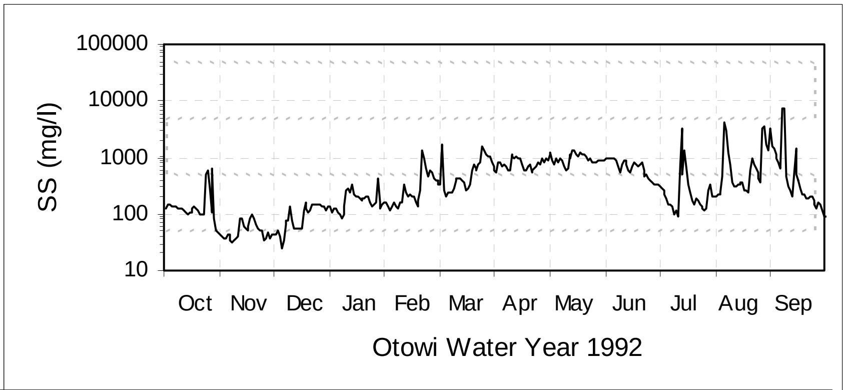

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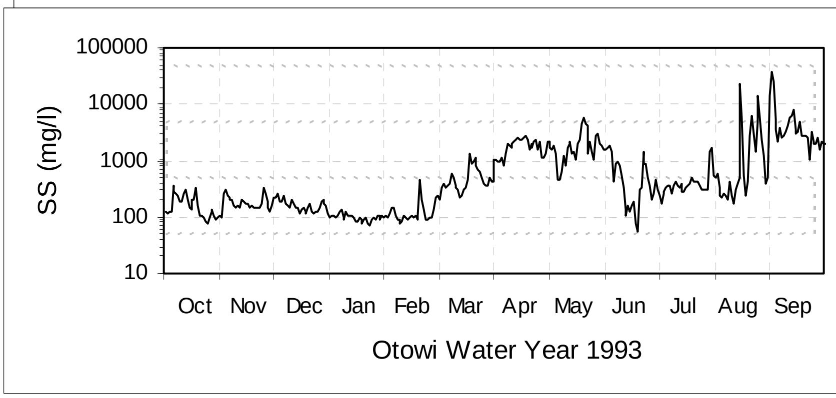

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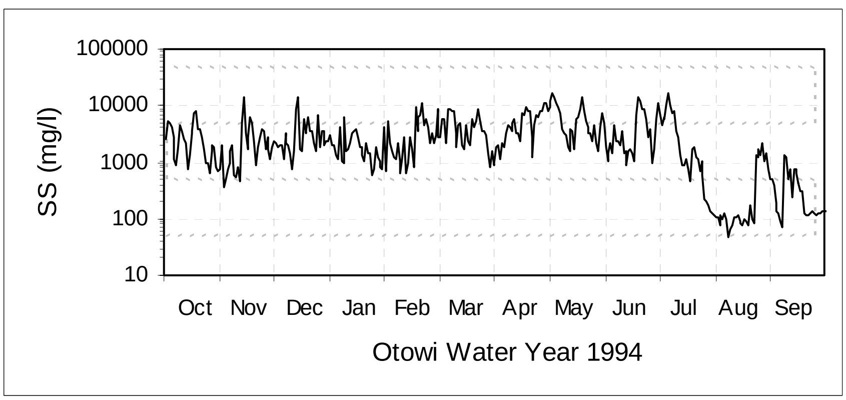

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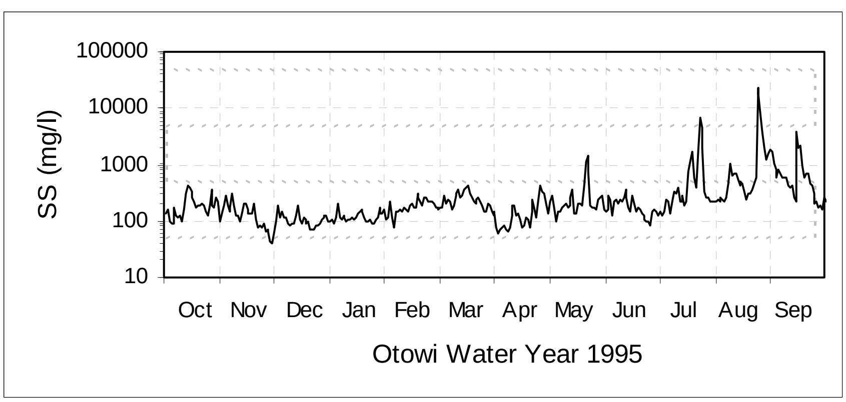

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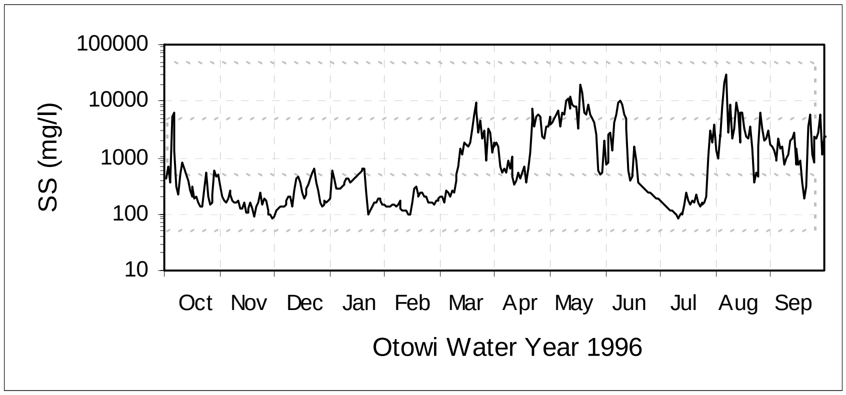
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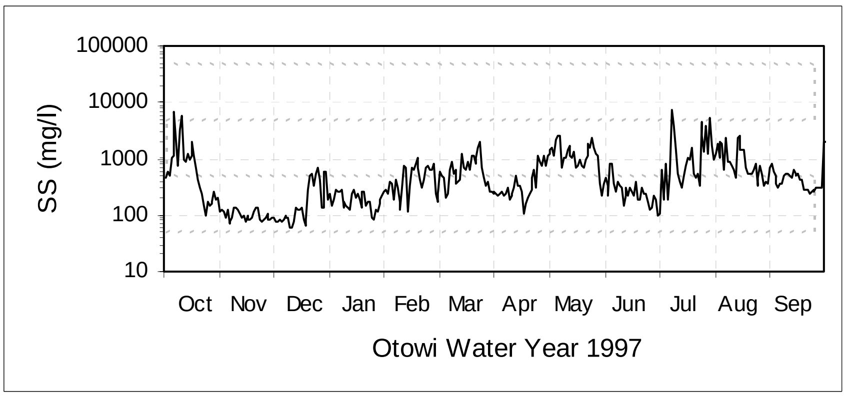
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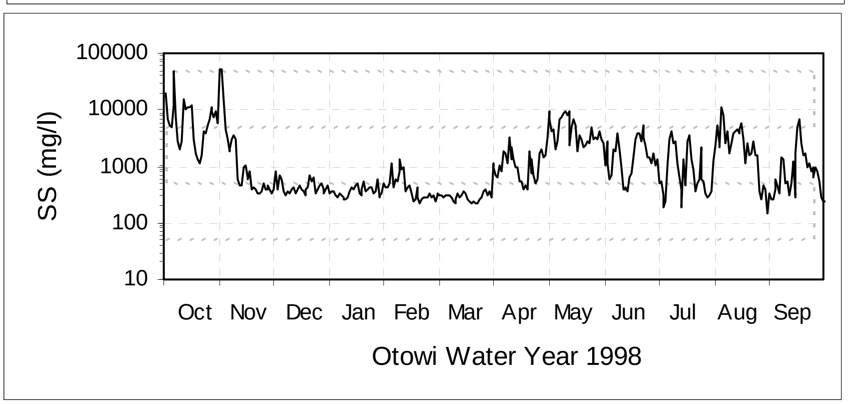
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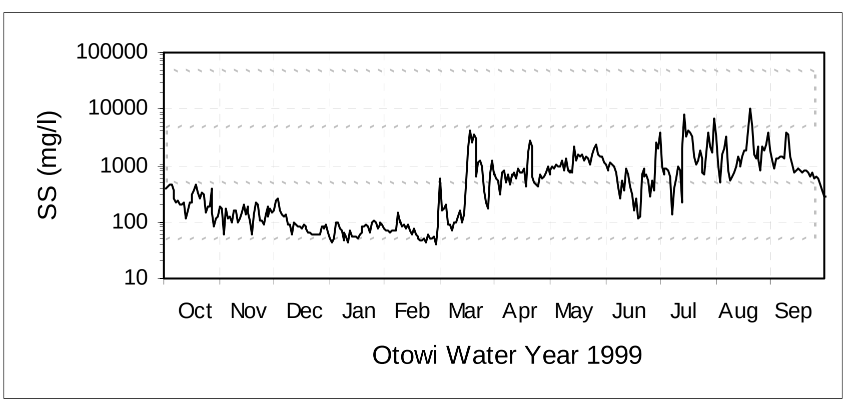
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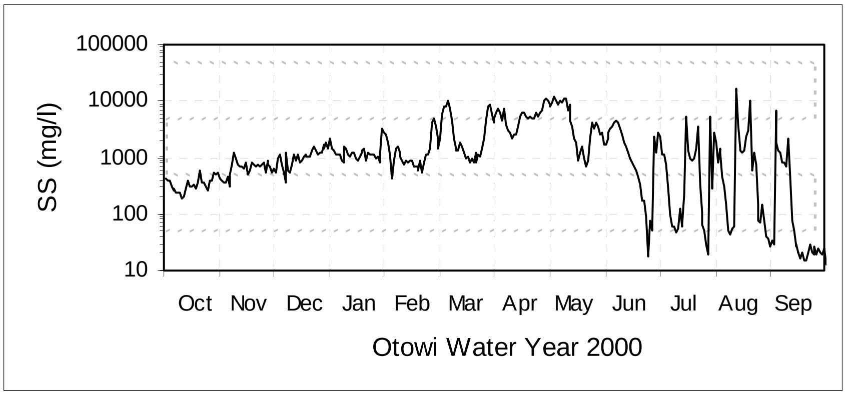


The time-series plots suggest three generalities:

(1) The 45-year record shows no obvious overall trend. While one might anticipate trend relationships between SS concentration, upstream regulation (e.g., Abiquiu Reservoir began operation in 1964), water use and land condition, whatever occurs is indiscernible in the ‘noise’ of the record.

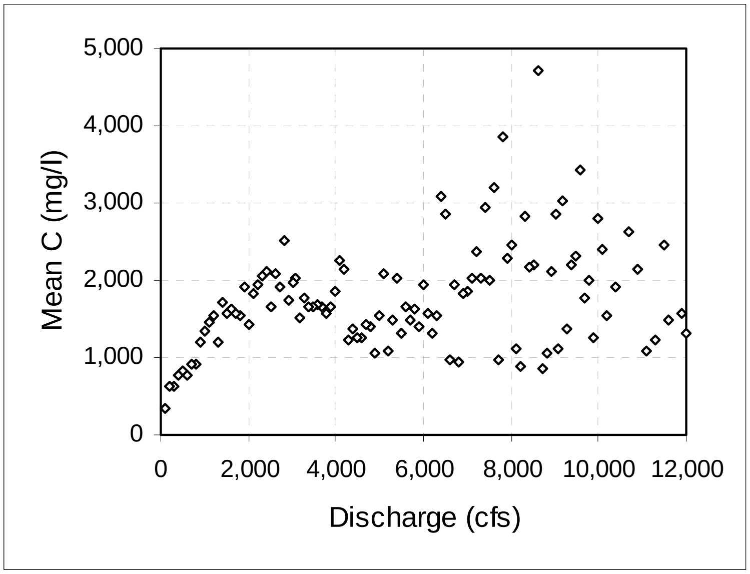
(2) No overall seasonal pattern of SS concentration predominates. The May-September SS concentration exceeds the October-April concentration in roughly half of the years and is roughly the same for most of the rest. Water Year 2000 is an exception. Following are mean monthly discharges.

Mean Monthly Discharge Q (cfs) at Otowi, 1885-1999

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
804	891	784	689	839	1,226	2,341	4,315	3,363	1,358	930	804

Q is substantially related to snowmelt. The more erratic, less sinusoidal SS record fails to mimic this seasonality. Were SS concentration to be regularly high in early summer, one might suspect that the snowmelt sweeps disproportionate overbank sediment into the channel. Were SS concentration depressed when Q is high, on the other hand, one might suspect SS to be bed-source limited. The poorly correlated Q and SS concentration record suggests neither general hypotheses. A supply-side model of SS seems unfruitful.

The following SS vs. Q plot represents 13,872 data pairs, 1955-1995. Plotting all the data yields a back cloud of points. This plot shows averages grouped by Q. Each point on the left side is the mean of 100-120 values. Each point on the right side is the mean of 20-30 values, as there were fewer large Q’s.



Q and SS concentration are correlated up to Q of approximately 2000 cfs. The higher the discharge, the greater the turbulent diffusivity, and thus the higher the SS. Higher Q's show virtually no SS correspondence, suggesting, again theoretically anticipated, an upper limit on turbulence.

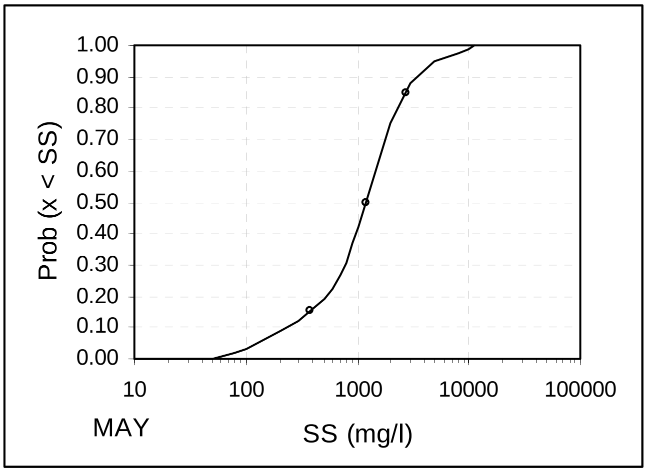
(3) The SS concentration record is erratic over the short term for most of the year, but particularly so in May-September. In many years, such variance is dramatically greater than seasonal change. This suggests that SS concentration responds to rapid change, albeit small in some cases, in Q. May-September is the season of short, convective rainfall. This is also the period in which upstream reservoirs release on a daily basis for specific demands. Pulsed Q picks up suspendable material from the bed, there in ample quantity. Subsequent streamflow is sufficient to keep much of the material in suspension. Presumably, such sort-term "overload" deposits in Cochiti Reservoir.

The three observations can be combined. May-September SS concentration is erratic, not well explained by steady-state transport mechanics. There is thus little reason to pursue one of the many river transport models (Yang, Meyer-Peter, Einstein, etc.). The intake should be designed for an SS concentration determined from the empirical record. The preceding figure suggests that this record is reasonably fit by,

SS (mg/l) = 500 + 0.75 Q (cfs), Q < 2000

SS (mg/l) = 2000, Q (cfs) > 2000

The short-term variability makes SS loading a stochastic problem. To that end, one can express SS concentration as probably of exceedance, as one would do with flood flows. The following five figures plot SS probably of non-exceedance by month over the 45 year record. The three points represent 15, 50 and 85 percent probabilities.


1.00
0.90
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Prob (x < SS)
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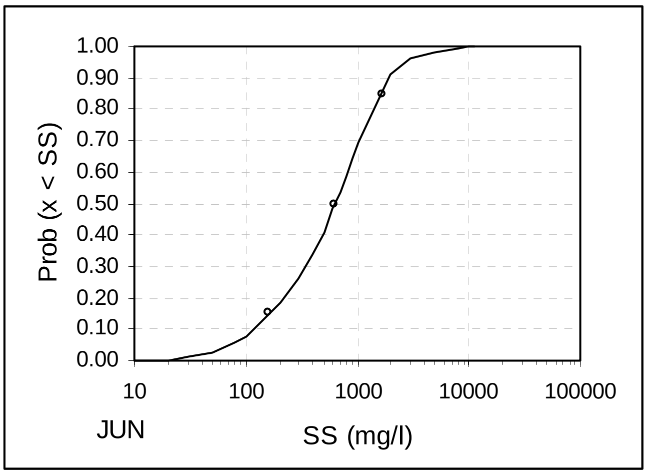
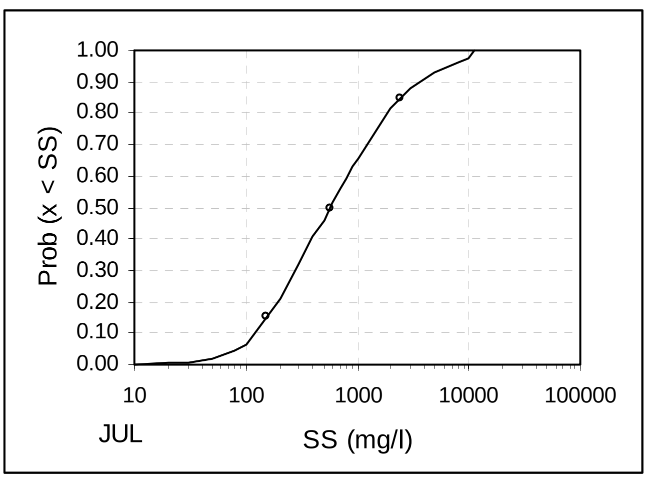
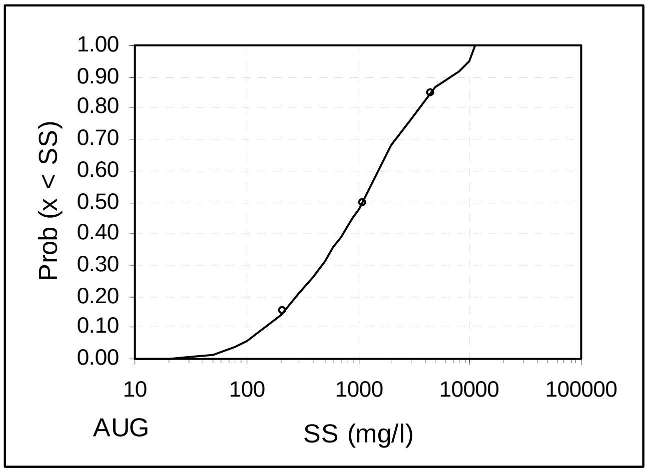
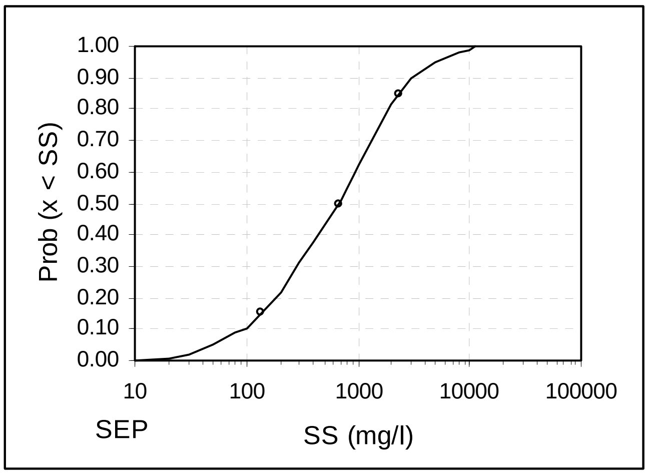
10000
100000
MAY
SS (mg/l)


1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Prob (x < SS)
10
100
1000
10000
100000
JUN
SS (mg/l)


1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Prob (x < SS)
10
100
1000
10000
100000
JUL
SS (mg/l)





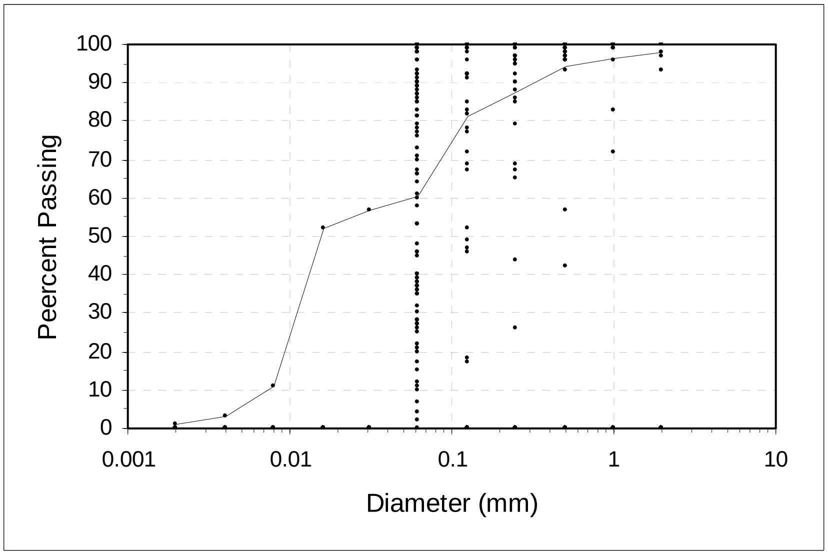
The table summarizes the distributions.

Suspended Solids (mg/l)					
Prob (x<SS)	Month				
	May	June	July	Aug	Sept
0.15	373	162	151	210	133
0.50	1185	628	568	1089	670
0.85	2759	1644	2456	4569	2339

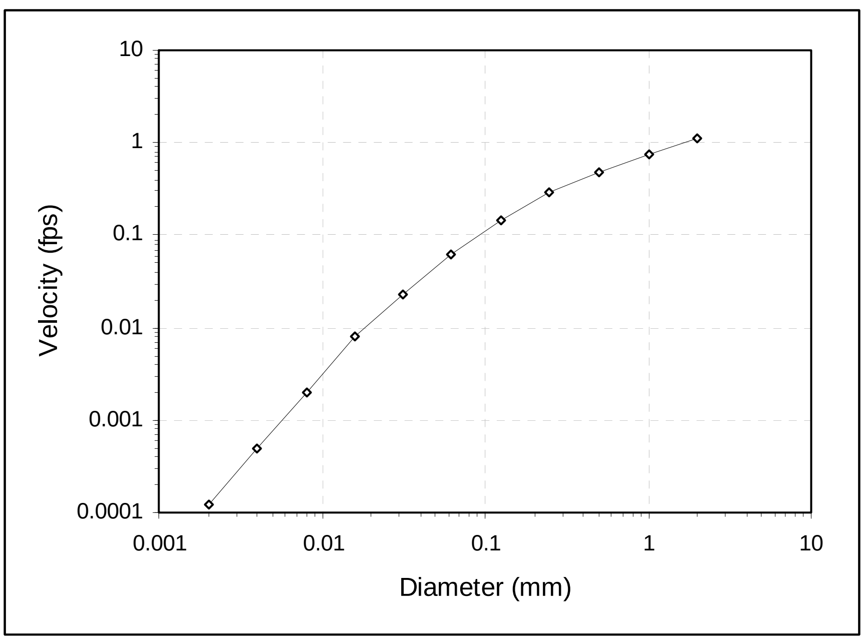
May and August, on the average, have the highest modes, roughly 1100 mg/l. One, however, would not size an intake for what occurs just half the time. If one, for example, wished to size the facility for a 15 percent exceedance probability, one might size for the 3000 mg/l range. An intake sized for this loading will be underutilized 85 percent of the time.

2000 mg/l is a reasonable conclusion from both the probability data and the earlier rough regression. Final design should be based on a prudent tradeoff between risk, economics and operation.

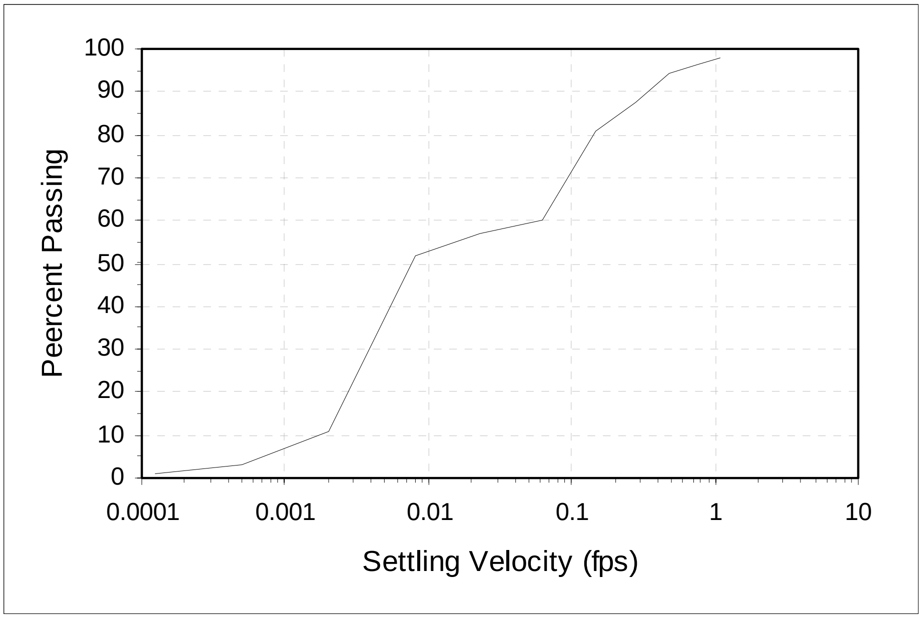
The following figure of SS size distribution is drawn from 87 gradation measurements in May-September. The plot shows the individual points and the means. The curve is relatively unreliable below 0.05 mm, as few measurements exist for this fine portion.



The next figure relates settling velocity to particle size. The leftmost three points are theoretical, as velocities are too slow for practical measurement. The remaining points are NRCS handbook values (NEH Sec. 3, Chapter 1, p. 2-10).



The subsequent figure transforms sizes to a corresponding setting velocity distribution.



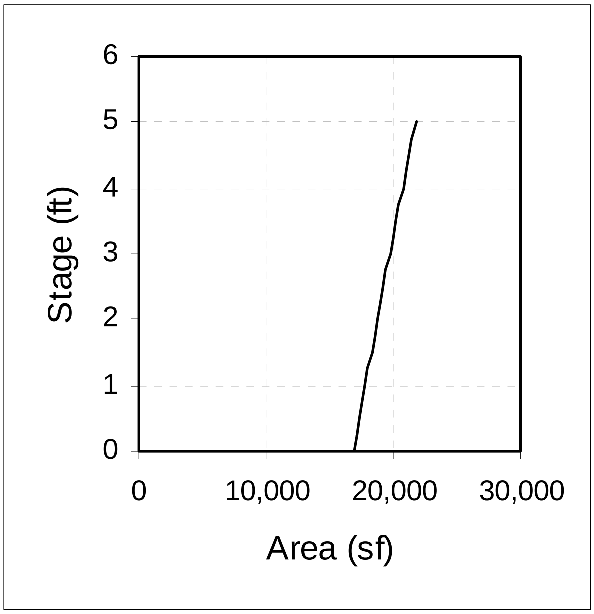
Part Two: Intake Design

The intake consists of the following components:

(1) A multi-screened intake in the river. The proposed 1.75-mm opening is reasonable based on the particles. Bedload will not pass 1.75-mm slots and local (abutment-type) scour should preclude bedload piling in front of the screen. A 1-mm opening only slightly reduces the material passing the screen and would create higher entrance head loss. Manufacturer 's specs are needed to pursue this topic.

This study presumes no SS removal at the screen. Occasional material exceeding 1.75 mm may lodge in the grating, but most of what doesn't enter through the screen will be then swept onward in the main channel. 1-mm particles may settle behind the screen in the compartments just upstream of the pipe leading to the proposed low-head submersible pumps. Sloping and sculpting the intake bottom can help sweep such deposition onward into the conduit (item 2). As the screen will collect occasional floating debris, it must be monitored, sparged with compressed air, and/or raked clean as needed.

(2) A sedimentation basin, here assumed to be 0.5-acres, 5 feet deep with 2:1 sideslopes. Flow into the basin would be via a pipe leading from low-head submersible pumps located just east of the intake. Following is the rough stage-area curve for the assumed basin.



(3) Outflow pump and piping from the basin to the water's destination, not a topic of this report.

The assumed overall annual capacity for the described system would be about 15,000 acre-feet/year, is 20.7 cfs, with an intake peak design capacity of about 25 cfs.

Basin sedimentation analysis is dynamic in the following senses:

(1) Discharge into and out of the basin can vary with time (but doesn't in this study because discharge is presumed to be constant.)

(2) Flow rates into and out of the basin need not be the same (but are the same in this study because the basin is assumed to be always full).

(2) Inflow SS concentration can change (but in this study is assumed constant at 2,000 mg/l).

(3) Surface area changes with stage.

(4) Basin capacity decreases as the bottom accumulates deposition.

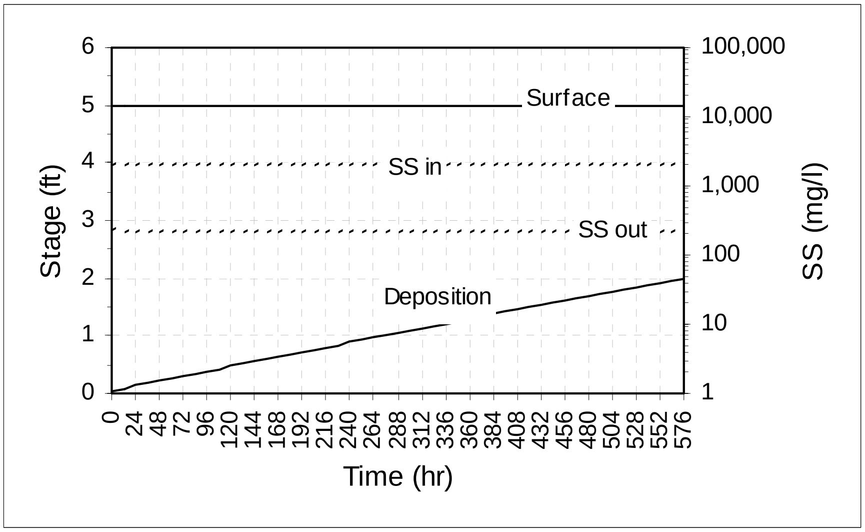
(5) Outflow rate adjusts as necessary to conserve water and sediment. As the basin accumulates deposition over time, its effective water storage decreases.

Sedimentation efficiency is modeled for each of the 11 SS sizes measured at Otowi by the conventional settling/upflow velocity ratio method.

A 0.90 basin efficiency is applied to the overall removal, implying that 10 percent of SS resuspends and leaves with the outflow. This efficiency approximates the performance of a well-functioning urban desilting basin. If inflow is not introduced in a relatively smooth manner and/or the outflow pumping disturbs a significant portion of the pond's quiescence, efficiency should be lowered. Lowered efficiency shifts SS from the basin to the upstream treatment. Lowered efficiency also subjects the pump and upstream piping to more abrasion.

A 0.90 basin efficiency is not the same as decreasing settling velocities by 10 percent, a safety-factor used in some models. The latter adjustment has virtually no effect on this study's performance, where falling 10 percent slower, the particles still reach the bottom. This study's efficiency moves some SS through the basin, independent of particle characteristics.

The following plot shows basin performance for 24 days. The water surface stays at 5 feet while the bed rises 2.0 feet.



Outflow SS varies between 220 and 237 mg/l. Deposition averages 53.8 yards/day. Subsequent water treatment has an additional 6.7 yards/day of sediment with which to contend.

The model run for a longer period fills the basin with deposition -- what common sense says happens. The 24 day run represents as long as the basin might go, on the average, between cleanings. As river SS concentration changes, so does deposition. A more-realistically modeled scenario would show the basin floor relatively unchanged for a period and then sharp rising corresponding to a SS peak in the Rio Grande.

10,000 mg/l SS on the river (seen 1 percent of the May-September days) will fill the basin with 4 feet of sediment in just ten days, however. For the period before the project is brought to full capacity, the rate of filling would be less. Whatever mechanism is chosen to clean the basin must, thus, be always on standby. Cleaning options include:

(1) If the 0.5-acre basin were narrow, its bed could be backhoe-accessible. Excavation equipment could be driven to secure parking.

(2) The bed could be draglined. Fixed equipment will be less secure.

(3) Excavated spoil could be trucked to the nearby Canada Ancha Arroyo alluvial fan. Fifty four yards/day is negligible compared with either the sediment geologically there or the load borne into the Rio Grande in ephemeral runoff events.

(4) Excavated spoil could be trucked from the floodplain. A heavy haul road would need improvement, fuel would be expended and the dumped spoil may have environmental consequence. Long haul trucking will require a full-time driver. If there are nearby large holes to fill, this option may look better.

(5) Excavated spoil could be placed back in the river or along the bank for subsequent erosion. Spoil will generally be between one-tenth and one-hundredth of the SS naturally in the river. Returned spoil would not likely have noticeable geomorphic or significant environmental impact (a topic meriting further description if the option is pursued). Immediate return impacts the smallest riparian area. All river sediment was destined for Cochiti Reservoir before the project. Ending up in Cochiti after the project is, in broad sense, zero change.

(6) Deposition could be dredged and slurried to its destination, albeit the Canada Ancha, an uphill site or back to the river. Slurrying will have less vehicular impact on the bosque than would trucking, but would leave piping exposed to floods. Slurry water may trigger water rights and environmental issues.